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ABSTRACT

The purpose of this paper is to discuss ways in which developmental psychology suffers from the lack of an appropriate technology of measurement and statistical analysis. The paper begins by noting that developmental psychology is the study of change; that individuals develop through a succession of "stages" which are separated by periods of transition. Individual structural theorists differ in their emphasis on the nature, speciticity, and discreteness of the stages, and the reversibility of development; but the fundamental notion of structures, their differentiation and integration are common. Problems with assessing developmental variables come about because they are ordinal, and not interval, in nature; the conception of reliability as stability over time is not viable; internal consistency is, likewise, not a sound criterion of reliability; and distributions of developmental assessment are non-normal, and the shape of the distribution would be expected to be different for different age groups. There are also special problems of research design, data collection, and data analysis which research in development poses. To resolve some of these problems, it is suggested that developmental psychologists sit down with measurement people and design ways of analyzing measurement problems, so that measurement and statistics can become a tool to advance developmental theory. (BW)

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The Measurement of Developmental Variables: An Overview

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THE MEASUREMENT OF DEVELOPMENTAL VARIABLES: AN OVERVIEW

Over the past several years, a variety of individuals have voiced concerns regarding the relationship of the methods of inquiry available to researchers and educators to the conduct of psychologically meaningful research (e.g., Anastasi, 1967; Glaser, 1981). In his recent paper presented at the Buros-Nebraska Symposium, Gene Glass (in press) both summarized and elaborated on the apparent separation of the field of measurement and statistics from the behavioral and social science base which it was originally designed to serve. He made the point that, in order to conduct research using the rather sophisticated measurement procedures and statistical techniques currently available, one is constrained to adapt the psychological constructs to fit the demands of the measurement tools. He went on to argue that, because of this phenomenon, many of the more important psychological variables were remaining unstudied, or were being studied in ways which stripped them of their relevance to human functioning.

It is important to recognize that psychological theory has implicit assumptions about the nature of the variables which it construes as meaningful. That is, any psychological theory defines its constructs in ways consistent with an overall approach to understanding the phenomena of interest to that theory, and these constructs will have properties which have implications for

how they can be assessed without doing violence to the underlying psychological theory. At the same time, any measurement technique has implicit in it assumptions about the nature of the psychological variables which it can be used to assess. Thus, when a measurement technique is developed, it contains certain assumptions about the nature of what is being measured. When the nature of the underlying psychological characteristics are not consistent with that assumed by the measurement techniques then the relations between what is studied using those techniques becomes questionable in terms of validating or even being relevant to the psychological theory.

As a developmental psychologist, I have repeatedly come up against problems in analyzing my data from both sides of the issue. I have had traditional statistics and measurement training, including multivariate techniques and a fairly traditional course in measurement theory. I feel that I understand, at a conceptual level, the nature of the measurement and statistical techniques available to me to develop and test various psychological hypotheses. However, this has not sufficed. I have been thwarted in both ways. The procedures which I feel I need to use to gather data which seems to me to be the most meaningful for the hypotheses that I want to test do not meet assumptions of standard measurement theory. When I do gather data which seems to me to be meaningful, and which shows patterns

consistent with what theory suggests should be the case, I find that I do not have the statistical procedures available which can be used to demonstrate that these results are, in fact, meaningful (even if I could be sure my assessment techniques were reliable and valid.)

These frustrations made me particularly susceptible to the argument that was being advanced by Dr. Glass, and I felt that perhaps the time had come to be more concrete about the problems which were being pointed out. Thus, the purpose of this paper is to discuss some ways in which developmental psychology suffers from the lack of an appropriate technology of measurement and statistical analysis. Presentation and analysis of these problems can, hopefully, provide a way of reuniting psychological and measurement theorists in ways which will contribute to both the development of psychological theory and more flexible and relevant assessment techniques and methods of statistical analysis.

It is only fair to point out that much of what I will discuss is not original. Pieces of the problems have been discussed (e.g., Froman & Hubert, 1980; Moshman, 1977, 1981; Freidrich, 1972; Thomas, 1977; Uzgiris & Hunt, 1975; Wohlwill, 1973). However, the bulk of the discussion has been ad hoc rather than directed at the general nature of the problem. In addition, primary attention appears to be in the area of appropriate research design and statistical procedures. In general, the

problem of the implications of the nature of the assumptions of certain branches of developmental psychology for what constitutes appropriate measurement techniques is ignored. I am not convinced such neglect is justified.

The Study of Psychological Development. Probably the first place to start in attempting to analyze the need of developmental psychology in terms of the methodology which will enable it to advance knowledge is to analyze the nature of the discipline itself.

First and foremost, the study of development is the study of change. Some theories hold that change is continuous, occurring through the simple accretion of behavior (e.g., Baer, 1970). Currently, a significant portion of developmental psychologists view development from the perspective of change as being more or less discontinuous, resulting from the progressive coordination of more or less independent organizations into increasingly complex and hierarchically organized "structures" (Werner, 1948/1961; Piaget, 1970; Erikson, 1959/1980; Furth, 1970; Harvey, Hunt & Schroder, 1961; Kohlberg, 1969; Youniss, 1982). There are other researchers whose work is consistent with a structuralist perspective although they do not explicitly espouse that tradition (Perry, 1970; Loevinger, 1976; and Freud, S., 1926/1936, 1905/1938).

The theories which view development as a continuous process have some of the problems which will be addressed in this paper, notably problems with the nature of reliability in assessing change. However, the assumptions of their approach are generally consistent with those of dominant measurement techniques, and many of the other problems I will discuss are not as critical for these theories. The structuralist theories, however, have problems with a vengance (cf., Froman & Hubert, 1980; Kolm, 1981)!

While there are many varieties of structuralists there are some common characteristics of the various approaches. Since Piaget's model is the best articulated, I will use his description of developmental change as the basis for this discussion. It is my sense that the arguments apply with minor modifications to any structural position.

The structuralist perspective of development makes the basic assumption that individuals function as organized wholes. These wholes are presumed to consist of elements or parts which are related to each other by a "transformation" or "rule" in such a way that the whole has properties which are different than the properties of the parts. Some general categories of such structures which are important for human functioning include behavioral structures (e.g., tieing a bow or walking), language (e.g., sentences), conceptual structures (e.g., hierarchical

systems of concepts like the animal kingdom or the number system), and affective structures (e.g., values).

Development proceeds by a process of structural change involving differentiation of existing structures and reintegration of the differentiated structures into a new whole. While this does lead to a general progression from simple to complex, the more complex is not simply linearly or additively so. The more complex is also more organized and qualitatively different from the more simple. Thus the sentence is more complex than the word, it is also different from the word (usually). (Werner & Kaplan, 1963.)

At any point in the developmental sequence, individuals possess organized psychological structures which they use to interact with the environment. The organizations of that level of development are isolated from each other in a psychological sense; that is, they function independently of each other. As encounters with the environment occur, these organizations begin to come into contact with each other and, eventually, a coordination occurs between them which integrates them into a new, and higher level, organization. There are differences among structural theorists about the source of these new structures. Some argue for the unfolding of hereditarily determined structures (e.g., Gesell, 1940; Gesell & Ilg, 1946; Gesell, Ilg & Ames, 1956), some for environmentally determined organizations (e.g., Feldman, 1981),

and some for the construction of such organizations by the individual out of the interaction of individual and environment (e.g., Erikson, 1963; Kohlberg, 1969; Piaget, 1970) but the sequence of appearance of more complex psychological organizations is common to all theories in this group.

The coordinations made in any given stage remain independent of each other when they do not come into juxtaposition through repeated interaction in the same environment, even when they can be seen as embodying the same organizing principle. For example, a student learning to classify mammals and learning the various behaviors characteristic of a given occupation is using the classification operation both times, but the systems which are constructed have such different content and operate on such different environments that they remain separate during the concrete operational period. Thus we have the phenomenon which Piaget calls decalage (Flavell, 1963; Piaget, 1972.) This decalage does not only occur when areas are widely disparate in content. Even tasks which appear similar to outside observers may be isolated in the psychological structures of the individual if the content is sufficiently dissimilar in that individual's experience. It does appear, however, that once "enough" coordinations occur at a given stage, the underlying commonality is also seen, and progression to the next level occurs (Piaget, 1960; Erikson, 1963, 1959/1980; Feldman, 1980).

During the period when new coordinations are being constructed, individuals are in a period of transition. Transition states have their own characteristics. Because individuals are unclear just which organization to use, behavior tends to be erratic. Sometimes, one organization is used, sometimes another, sometimes exploration of possible coordinations occurs (Inhelder, Sinclair & Bovet, 1974). While these transition periods occur in the coordination of individual structures, there is also evidence for general periods of transition in which many structures seem to be undergoing change (Gesell, 1940; Gesell & Ilg, 1946; Gesell, Ilg & Ames, 1956).

Once the new structure is coordinated, behavior typically undergoes a marked change. In many cases, the old behavior disappears never to reappear (Inhelder & Piaget, 1924/1964; Uzgiris & Hunt, 1975). Thus, for example, a child who understands conservation of liquid does not revert to saying that one glass has more or less water based on one of its dimensions. On the other hand, the earlier structures are presumed to be necessary for and integrated into the subsequent structure. For example, children would not develop conservation of liquid if they did not first use the conservation of length structure which enables them to have the judgments that the quantity was "more because it's taller" and "less because its narrower" which then can come into play in the same situation.

From this perspective, individuals develop through a succession of "stages" which are separated by periods of transition. Individual structuralist theorists differ in their emphasis on the nature, specificity, and discreteness of the stages, and the reversibility of development. But the fundamental notion of structures, their differentiation and integration are common.

The Nature of Developmental Variables. This overall view of development presented above has implications for the nature of the variables which will be meaningful both for the study of development in the sense of investigating the validity of these models and developing new theory and for the use of developmental information in such applied settings as education, parenting, or psychotherapy. This nature, however, is quite different from that usually dealt with in measurement theory.

The first, and most obvious characteristic of such variables is that they are ordinal in nature. This is the characteristic which has received the most attention in the literature attempting to verify Piaget's theory (Brainerd & Brainerd, 1972; Brainerd & Fraser, 1975; Uzgiris & Hunt, 1975). Stage changes are presumed to occur in sequence, but it is not possible to specify a constant rate of change because individuals are not exposed to the environment in which the changes are facilitated at a constant rate. Even if one assumes that these changes are genetically

caused, variations in the genotype will not allow a specification of such constant rate. (This is why age is not a satisfactory variable for the study of development. Age would be an ideal measure in the sense that it is a ratio scale, but both theory and data suggest that it is not an independent or dependent variable of importance in the study of developmental phenomena (Uzgiris & Hunt, 1975).) Ordinality violates the assumptions of the usual "t" and F tests of parametric statistics and makes the use of such statistics questionable.

One way which has been used to get around this difficulty is to assign a stage score to a variety of tasks which are presented to subjects, and then to average the ordinal scores for each task into an overall score. This is essentially consistent with theoretical considerations in that stage functioning is considered to be more consolidated as more and more tasks are performed with the characteristics of the stage. The procedure has also been shown to become a better and better approximation of an interval scale as more items are included. However, in any averaging procedure, there will be score points which are not represented, and thus the actual scale will not be interval in nature. Fortunately, Bradley (1968) has demonstrated that it makes no difference in the distribution of the test statistic whether or not scores are continuous or discrete.

A further problem with assessments of developmental variables, whether or not they are ordinal in nature, is the nature of reliability. Since to study development is to study change, the conception of reliability as stability over time is not viable. Developmental instruments may be expected to be generally less reliable on time stability measures than non-developmental measures. This is true, no matter what the nature of the conception of developmental change. Even those theories which hold an accretion assumption should find that the occurrence of change over time lessens the reliability of their techniques. In a theoretical sense, such unreliability should be a characteristic of assessments of development so that these assessments are sensitive to developmental change, and the common procedure of making assessments close together in time only masks the issue. If they are not sensitive to change, then there is some question as to their conceptual validity as developmental assessments.

Uzgiris and Hunt (1975) did a relatively careful analysis of this problem in their development of ordinal scales of infant development. They found, not surprisingly, that test-retest stability was high over a 48-hour period for well established actions, but fell dramatically for tasks which were in the process of becoming organized, that is, in transition.

This finding in the context of the structuralist approach to development is theoretically meaningful. It establishes the

empirical reality of the transition phenomenon, and it seems to me to do violence to the theory to dismiss this as lack of reliability. Another interesting implication of the fact that assessments of stage functioning is not reliably assessable during transitions is that when assessment is done using a sample of individuals who are generally in age ranges where much transitional behavior seems to be occurring, such assessment will have a high probability of unreliability, affecting the outcome of statistical analyses which assume such reliability. This seems to indicate that the identification of transitional states may be an important assessment technique, and meaningful developmental assessments should not use dichotomous items. What we need, it seems to me, is a way to reliably assess change.

Internal consistency assessments of reliability are also a problem. The decalage phenomenon suggests that within a level of development individual achievements are very much a function of individual experience. Thus, the demonstration of stage functioning on one task is not a guarantee of the ability to demonstrate stage functioning in others. Studies of several levels of development have demonstrated the validity of this phenomenon. Uzgiris and Hunt (1975) found that, organizing their results in terms of Piaget's (1952) six stages of sensori-motor development, the tasks within these stages did not replicate the order described by Piaget. Brainerd & Brainerd (1972) and others

have found similar discrepancies within concrete operations and Piaget (1972) and Neimark (1975) discuss similar phenomena in formal operations. All of this indicates that assessment instruments which use a variety of tasks may not exhibit acceptable levels of internal consistency. This is, however, a function of the nature of the phenomenon being assessed, not the unreliability of the test. Again, use of such indices may "throw the baby out with the wash."

The reliability measure that is most valid from a theoretical point of view is that of inter-rater reliability. There are various ways of assessing this ranging from the percent agreement approach (as used by Uzgiris and Hunt, 1975) to an analysis of variance technique described by Winer (1962). A question which immediately arises is that of the "meaning" of the techniques and their comparability across studies. No apparent guidelines of what to use and why exist.

Distributions of Developmental Variables. Problems of good measurement theory for variables important in the study of development are exacerbated by distributional problems, particularly for stage theories. From a theoretical perspective it is expected that, issues of ordinality aside, distributions of developmental assessment will be non-normal. To make matters worse, not only should they be non-normal, the shape of the distribution would be expected to be different for different age

groups. For example, when a group of five year olds is assessed for concrete operations the distribution might be expected to be quite peaked because many individuals will be exhibiting preoperational thinking and only a few will be concrete operational. At age eight the distribution will have flattened out, only to peak again just prior to the onset of adolescence. This means that homogeneity of variance assumptions may be violated.

Kolm (1981) demonstrated the accuracy of these expectations within a junior high population. He tested the robustness of a variety of statistical analyses performed on this data with inconsistent results. Sometimes the tests were robust and sometimes they were not. He could discover no particular pattern.

The Design and Analysis of Developmental Research. Aside from problems of measurement, there are also problems which are unique to developmental research. Again, these problems are worst in approaches which are oriented toward examining qualitative changes.

The special problems of research design, data collection and data analysis which research in development poses for statistical procedures have been discussed with more frequency than those of measurement (Baltes, 1968; Brainerd & Brainerd, 1972; Friedrich, 1972; Froman & Hubert, 1980; Kolm, 1981; Moshman, 1977, 1982; Schaie, 1965; Thomas, 1977; Wohlwill, 1973). It is useful, however, in an analysis such as this to make some acknowledgement

of those in the context of the types of questions developmentalists need answers to.

Basically, developmental psychologists are interested in describing developmental changes--determining whether or not changes in various areas of development are synchronous, convergent, divergent or reciprocally interact (Wohlwill, 1973), investigating the possibility of hierarchical integration of sequential achievement, and determining the role of experience in developmental change.

Work building on that of Baltes (1968) and Shaie (1965) has begun to deal with the need for controls for historical context, time of measurement, etc. through the application of a combination of cross-sectional and longitudinal designs. These are parametric procedures and hold great promise so long as normality and homogeneity of variance assumptions hold. These procedures have been used primarily with assessment techniques which assume interval scales and normal distributions, and, implicitly, the continuous/accretion model of development. The general design characteristics would be useful for stage models, and the applicability of this approach to design for such models should be established.

Questions of sequential order and hierarchical organization are being addressed in at least two different ways. Because of the ordinal nature of the variables in question, nonparametric

techniques are being proposed to study sequentiality. The problem with this is the occurrence of meaningful zero cell frequencies. Ways to deal with this problem via model fitting assumptions are being proposed through techniques which allow expected cell frequencies to be zero (Froman & Hubert, 1980; Thomas, 1977). However, there is some disagreement about the validity of the Froman & Hubert procedure (Moshman, 1977, 1981) and the Thomas procedure does not work with zero observed frequencies--which are in accord with prediction. Clearly, work needs to be done in this area.

Another way that is being investigated as a potential means of addressing the hierarchical organization issue is being pursued by Wise (1982, 1983) and Wise and Bart (1984) who are using ordering theory as a basis for measuring hierarchies. There are a couple of problems with the current approach which needs dichotomous items and, ideally, a response consistent with early levels of development to precede those of later levels. For reasons discussed above, dichotomous items do not reflect meaningful transition states, and responses characteristic of earlier levels may never reappear once that level has been transcended. That is not to say that this avenue should not be pursued. It should be developed in close conjunction with developmental psychologists.

Determining the role of experience in development will require a variant of the cross-sectional-longitudinal designs which

includes experimental intervention as a blocking variable. This is not at all impossible conceptually, but, particularly where the developmental models involve qualitative change, problems of zero (or very small) cell frequencies, or distributional characteristics need to be dealt with.

Next Steps. I have been dimly aware of the problems I have outlined here as they have arisen in my attempts to conceptualize my own research and analyze my own data. I continually find myself collapsing cells to avoid zero cell frequencies and/or assuming (or worse, forcing) normal distributions so that I can get my data to fit the demands of statistical procedures.

It was not until I directed Paul Kolm's (1981) dissertation that I became attuned to the scope of the problem. I have come to wonder if the comment made by Froman and Hubert that

> Unfortunately, conventional measures of assocation are probably inadequate for the assessment of most detailed developmental propositions, ranging from simple descriptions of developmental priority (Brainerd & Brainerd, 1971) to complex patterns between developmental variables that are characterized as horizontal decalage, reciprocal interaction, and so on (see Wohlwill, 1973). In fact, since the data analysis strategies that are routinely applied to the study of staging appear to be incapable of evaluating many of the

> hypotheses that have been proposed and discussed in developmental psychology, it may be argued that data are now being wasted or, at the very least, underused due to a lack of available appropriateness in our common statistical methods. (p. 136)

could not be extended to cover all of the research in developmental psychology, not just that on developmental priority. I am sure that I have not covered all potential problems. This leads me to wonder what confidence can be placed in the existing literature in the field.

It is my view that what is needed is consistent with Dr. Glass' (1983) call for a reintegration of psychology and measurement at very basic levels. In the field of developmental psychology this requires, it seems to me, developmental psychologists sitting down with measurement people and, starting from the very beginning, designing ways of analyzing measurement problems, so that measurement and statistics can become a tool to advance developmental theory in ways it cannot at this point. I think this problem needs to be dealt with as a whole since it is the results of the application of measurement techniques which are used in the procedures for statistical analysis (even nonparametric procedures in developmental psychology). Current efforts seem to be in the area of statistical analysis and

research design, but these efforts ignore the characteristics of the measures being used as data.

It will take a good deal of creativity to deal with these problems, but it could be fun.

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